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(54) Title: MOVABLE X-RAY SOURCE WITH OR WITHOUT COLLIMATOR

(57) Abstract

The new x-ray arrangement for the radiography of large objects, eliminates the disadvantages of the x-ray arrangements used today, namely the image distortion, and the need of high x-ray energy, and considerable radiation protection. The arrangement allows the creation of a simplified form of tomography and 3-D images. The arrangement consists of a movable, scanning x-ray emitter characterized firstly by the fact that the target of the electronic beam is movable, and may be moved according to a predetermined, regular moving pattern along the lengthened anode, secondly by the fact that the x-ray emitter is placed near the object. The emitted radiation bundle is collimated with the help of one or more rotating, cylinder-shaped collimators encircled by a symmetric slit along the cylinder of each collimator for the x-ray beams to be parallelly scanned through the object. By using two or more coolimators in co-operation the image quality may be varied steplessly in connection with the production of images. The movable x-ray emitter may also be used in co-operation with other types of collimators than those described above to generate divergently scanning x-ray beams through the object or for radiographing objects without collimator or collimators.

MOVABLE X-RAY SOURCE WITH OR WITHOUT COLLIMATOR

(In this text the notion "x-ray beams" will be used in lieu of "ionized, electromagnetic beams".)

1. Description

General about Radiography

When radiographing large objects (cars, freight containers etc.) the object is placed between the x-ray emitter, usually a conventional x-ray apparatus for industrial purposes or an accelerator, and a detector registering the amount of radiation penetrating the object.

X-ray beams are generated when the electrons of a narrow, high-speed electronic beam is retarded against a target. The target, often a plate made of wolfram, from where the x-ray beams are emitted, is called the emitter, and the beams emerge as a straight line from the emitter, and at random in all directions. The emitter is almost pointed, and the divergent bundle of x-ray beams emerge from this point. The x-ray beams are electrically uncharged, and there is no way to guide the x-ray beams with the help of lenses or magnetic fields. In order to hinder x-ray beams in undesired directions the x-ray equipment is surrounded by x-ray absorbing material except in the direction the beams are desired. In this direction a bundle of divergent x-ray beams emerge. The bundle of beams may pass through a collimator, collimating the bundle of beams into a beam of desired dimensions. The bundle of beams is usually collimated with the help of one or more collimators into a divergent, fan-shaped bundle of beams or into divergently scanning x-ray beams of the flying-spot type, and a plane of divergent x-ray beams is created. When radiographing, the object is slowly moved perpendicular to the plane of x-ray beams between the emitter, and the detector system, and with the help of an image processing system an image is successively produced on a screen when the object passes through the plane of x-ray beams between the emitter and the detector. (This type of radiographic system is used at airports for the examination of hand luggage.) The problem with the collimators and the type of x-ray equipment used to-day is the inherent disadvantages and deficiencies of these devices when radiographing large objects.

Distance between the Emitter and the Detector

When radiographing large objects (cars, freight containers etc.) to-day the x-ray emitter must be placed relatively far away (between 5 to 10 metres) from the detector. As the intensity of radiotion is reduced by the square of the distance, when conventional x-ray equipment is used, the distance between the emitter and the detector results in low radiation intensity towards the detector. The reduction of radiation intensity towards the detector is compensated by emitting high x-ray energy in order to increase its ability to penetrate the object. The disadvantage of high x-ray energy is, however, a low-intensity image contrast.

One further disadvantage of the x-ray equipment used to-day is that the divergence of the bundle

of x-ray beams or the divergently scanning x-ray beams more or less enlarge the radiographed details in the object when presented on a screen, depending on the positions of the details in the object, so called image distortion. Details near the x-ray emitter are considerably enlarged while details near the detector are enlarged to a lesser degree. The degree of distortion is due to the divergence of the emerging bundle of x-ray beams. The distortion produced by a firm, pointed x-ray emitter is a considerable disadvantage, if the image is to be processed by a computor. The distortion also makes the image difficult to interprete.

Conclusions about the Design of X-ray Equipment used to-day

The inherent disadvantages and deficiencies of x-ray equipemnt used to-day in connection with the radiography of large objects implicate that there is a need of equipment eliminating these disadvantages and deficiences.

Movable X-ray Emitter with or without Collimator (Drawing 1.)

By a movable x-ray emitter is understood an emitter where the target of the electronic beam is movable, and thus moved according to a predetermined, regular moving pattern along the lengthened anode.

The movable x-ray emitter has foremost been designed to be used in combination with one or more rotating, cylinder-shaped collimators to generate parallelly scanning x-ray beams for the radiography of large objects. The innovation comprises both the the movable x-ray emitter itself, and the emitter in combination with one or more collimators. (A single, rotating, cylinder-shaped collimator is already known, but not in combination with a movable x-ray emitter.)

By placing the movable x-ray emitter just in front of a rotating, cylinder-shaped collimator close to the object, the need of high x-ray energy, and considerable radiation protection are eliminated as a consequense of the short distance between the emitter and the detector, and by radiographing the object by parallelly scanning in stead of divergently scanning x-ray beams the image distrotion is eliminated. The radiographing of the object by parallelly scanning x-ray beams is done by collimating the beam with the help of a rotating, cylinder-shaped collimator encircled by a symmetrical, (uniform) helical slit along the cylinder. As a consequense of the rotation of the collimator the x-ray beams are parallelly scanned through the object in stead of being divergently scanned through the object as is done when x-ray equipment of conventional design is used with a firm, pointed x-ray emitter. (The understanding of how the movable x-ray emitter is designed and functions in co-operation with one or more collimators for the generation of parallelly scanning x-ray beams through the object is facilitated by the description of the design and functioning of the "symmetric" collimator further forward in the text with its belonging five drawings.)

The to-day well known design of an x-ray equipment generating a narrow, divergently scanning x-ray (so called flying spot) in order to produce an x-ray image may thus be replaced by an x-ray equipment design where the x-ray is parallelly scanned through the object with the help of a mo

vable x-ray emitter. The design of the new arrangement is well suited for a movable emitter created by a sweeping electronic beam.

X-ray Emitter for the generation of a scanning Bundle of X-ray Beams (Drawing 1.)

The x-ray emitter for the generation of the scanning bundle of x-ray beams consists in part of an electronic beam gun (11), and in part of focusing equipment (12) for the generation of a narrow electronic beam (13) towards the lengthened anode (14). With the help of coils (15) with variable magnetic fields, the direction of the electronic beam, and consequently the target against the anode may be changed. The design is well known, and is used in connection with the horizontal guidance of the electronic beam of a conventional black-and-white TV-set when the target of the electronic beam towards the screen is moved from left to right in a perpetually repeated movement.

In the present case the scanning electronic beam (13) hits a lengthened target made of wolfram (14) angled approximately 70 ° towards the scanning plane of the electronic beam, and as a consequense of the retardation of the electrons against the target (so called bremsstrahlung, litterally braking radiation) the x-ray beams are generated in all directions. In our case the x-ray beams perpendicular to the plane of the scanning electronic beam are used. By scanning the direction of the electronic beam, the target of the beam against the anode will also be changed, and the point from where the x-ray beams are emitted, will be moved along the lengthened anode from the starting point (16) in one end (16) of the anode to the final point (17) in the other end (17) of the anode, timing the scanning electronic beam so that a parallelly scanning bundle of x-ray beams are generated in the anode. The x-ray emitter is surrounded by walls made of x-ray absorbing material, and is protected against radiation with the exception of a narrow, open slit towards the rotating, cylinder-shaped collimator, as long as the collimator, thus allowing a narrow, scanning bundle of x-ray beams to pass through the slit.

Rotating, cylinder-shaped Collimator for the generation of parallelly scanning X-ray Beams (Drawing 4.)

The collimator used for the generation of parallelly scanning x-ray beams through the object is a homogeneous, lengthened cylinder (31), made of x-ray absorbing material (e.g. lead). The collimator consists partly of a collimator part (31), partly of arrangements in both ends (32) of the cylinder for the suspension and guidance of the collimator. The collimator part of the lengthened cylinder (31) has an open slit (33) circling through or near the centre of the cylinder, and along the whole length of the cylinder, being the collimator part. The slit is helical, and the number of turns of the slit is dependant on the pitch, and the length of the collimator part. Each turn of the slit of the cylinder creates two "collimator holes" (34 and 35) towards the anode, and the number of "collimator holes" is thus dependant on the pitch of the slit, and the length of the collimator part. The open slit of the cylinder is symmetrically (uniformly) encircling the cylinder. If the slit (33) of the collimator is symmetrically encircling the cylinder, a "collimator hole" is produced through the centre of the cylinder, and perpendicular to the lengthened cylinder. ("Collimator

holes" in other directions will be produced, if the slit is unsymmetrically encircling the cylinder.) The "collimator hole" is physically no hole, but an open slit as broad as the width of the created "collimator hole", and as long as the length of the collimator part of the cylinder. Seen from the anode the slit looks like a hole as a consequense of the rotation of the cylinder. When the collimator rotates the "collimator holes", seen from the anode, will be perceived as a series of holes (34, 35, 36 and 37) perpetually moving in one direction along the collimator. The size of the radiographed object determines the dimensions of the collimator as well as the whole x-ray equipment.

Two or more rotating, cylinder-shaped Collimators in co-operation for the generation of parallelly scanning X-ray Beams, and for the possible adjustment of the "Collimator Holes" (Drawing 5.)

In order to be able to produce an acceptable quality of the image when radiographing, there is a need of adjusting the size of the aperture of the "collimator hole" which is normally done by changing collimators. The design of the rotating, cylinder-shaped collimator makes it possible adjust the aperture of the"collimator hole" steplessly without changing collimators when two or more collimators co-operate. For the adjustment of the "collimator hole" at least two co-operating collimators are needed.

If two or more collimators (41 and 42) with different diametres are mounted within each other, and the collimators are adjusted so that the encircling slits (43) are just in front of each other, the "collimator holes", seen from the anode, will be successively reduced, if the inner collimator (42) is adjusted (or is turned laterally) in relation to the outer collimator (41). The maximum size of the adjusted "collimator hole" is thus determined by the width of the open slit. When the adjustment is equal to the width of the slit (some millitetres) the "collimator hole" is fully closed, and no radiation will be able to pass through the collimators (41 and 42). By the relative adjustment of the collimators, the size of the "collimator hole" may be varied from maximum size down to fully closed. The fact that the size of the "collimator hole" determines the image quality means in practice that resolution may be indicated steplessly.

The "collimator hole" may also be adjusted, if two or more collimators are parallelly mounted one after the other in the radiation direction with the corresponding "collimator holes" in a straight line.

In this case the size of the "collimator hole" is adjusted by adjusting the parallelly mounted collimators (lengthways or latterally) in relation to each other. When the collimators are adjusted so that the "collimator holes" of each cylinder respectively, are in a straight line (exactly in front of each other), the "collimator hole" has a maximum aperture. If the cylinders are parallelly adjusted, lengthways or latterally, in relation to each other, the size of the aperture (cross section area) of the "collimator hole" is successively reduced. When the adjustment is equal to the width of the slits the aperture of the "collimator hole" towards the emitter is fully closed, and no radia

tion is able to pass through the collimators. By adjusting the collimators in relation to each other, the "collimator hole" may even in this case be varied from maximum to fully closed aperture. If more than one collimator is used, the collimators must be adjusted so that the corresponding "collimator holes" are in a straight line with the x-ray beams.

X-ray Emitter and Collimator or Collimators in co-operation (Drawings 2 and 3.)
If the velocity and direction of the rotating collimator (collimators) are adapted to the velocity of the target (22) of the sweeping electronic beam (21) along the anode (the movable emitting point) one "collimator hole" (23) will always be just in front of the movable emitting point (22). The "collimator hole" will move in front of the anode (24) at the same velocity as the bundle of x-ray beams being emitted; a parallelly scanning well-collimated x-ray beam (25) will be generated. The movement of the electronic beam (27) (and the movable emitter) will continue towards the end (26) of the anode, and when the end has been reached a new "collimator hole" (23) is opened up at the level of the starting point (22) of the anode (the starting point of the emitter) as a consequense of the rotation of the slit of the collimator. Simultaneously the electronic beam is moved instantly to the starting point (22) of the emitter, and a new scanning movement is started. Repeated. parallelly scanning x-ray beams are generated, moving themselves parallelly through the object (cf. the horizontal movement of the electronic beam of a black-and white TV-set), and a scanning plane i created. The velocity of the rotating collimator (collimators), the pitch of the slit of the collimator, and the velocity of the movable emitting point along the x-ray emitter determines the scanning velocity. If the object is slowly moved through the scanning plane, each scanning movement results in a new "slice" of the object being radiographed, and when the whole object has passed through the scanning plane, the whole object has been radiographed. In this way an image of the object is successively produced.

The best radiographic result is achieved if two or more collimators are used for the collimation of the bundle of x-ray beams being emitted from the x-ray emitter. One collimator is placed behind the emitter (between the emitter and the object), and another collimator just in front of the detector (between the object and the detector). The collimator in front of the object means that well-defined, scanning x-ray beam is generated through the object implying that very little secondary or scattered radiation is produced in the object as well as a better quality of the produced image. The collimator behind the object firstly means that the negligable secondary radiation produced in the object is hindered, secondly that the x-ray beam emerging from the object is further defined.

The movable x-ray emitter may also be used without collimator for the real time radiography of objects from different angles.

If one or more collimators are used togehter with the movable x-ray emitter divergently scanning x-ray beams are generated through the object subject to other types of collimators being used than those used for the generation of parallelly scanning x-ray beams.

The generation of a divergent bundle of x-ray beams or divegently scanning x-ray beams with the help of a movable x-ray emitter thus partly is the same technical achievement as the generation of parallelly scanning x-ray beams being collimated by one or more rotating, cylinder-shaped collimators, each with a symmetrically encircled slit along the cylinder. The difference is that the so called image distortion remains, if only a movable x-ray emitter is used with or without a collimator or collimators.

Conclusions about the Design of the new X-ray Arrangement

By placing the x-ray emitter considerably closer to the object than is possible with the way the x-ray emitter is designed to-day, low x-ray energy is sufficient which to a considerable extent reduces the need of radiation protection.

The new x-ray arrangement makes it possible to show images on a screen without distortion including both a simplified form of tomography and 3-D images, and by the stepless adjustment of the "collimator hole", if two or more collimators work together, the resolution range may be varied which makes the arrangement flexible.

3. Drawings

The design and functioning of the movable, scanning x-ray emitter are presented on three drawings. The rotating, cylinder-shaped collimator encircled by a symmetric slit along the cylinder is presented on two drawings. In total five drawings are enclosed.

Drawing 1. shows the functioning of the movable x-ray emitter. Figure 1. of the drawing shows the emitter seen from the side while figure 2. of the drawing shows the emitter seen from above.

Drawing 2. shows the movable x-ray emitter in combination with one rotating, cylinder-shaped collimator. Figure 3. of the drawing shows the emitter seen from the side, and at an inclined angle from above.

Drawing 3, figure 4. shows the emitter seen from above. Figure 5. of the drawing shows an enlargement of figure 4..

Drawing 4, figure 6. shows one simple, non-adjustable, rotating, cylinder-shaped collimator encircled by a symmetric slit along the cylinder.

Drawing 5. shows two rotating, cylinder-shaped collimators in co-operation with one cylinder mounted within the other with adjustable "collimator hole". Figure 7. of the drawing shows the collimators with fully open "collimator holes" (44, 45, 46 and 47) while figure 8. of the drawing shows the collimators turned 5° in relation to each other for the adjustment (reduction) of the size of the "collimator holes" (48, 49, 50 and 51).

4. Claims

1.Movable, scanning radiation emitter for the emission of a ionized, electromagnetic bundle of beams for the firm collimation together with a rotating, cylinder-shaped arrangement of lead or other radiation absorbing material (collimator) c h a r a c t e r i z e d b y t h e f a c t

- that the target of the electronic beam is movable, and is moved according to a predetermined, regular moving pattern along the lengthened anode
- that the radiation emitter (focus) is placed near, and in front of the rotating, cylinder-shaped arrangement (collimator)
- that the x-ray beam is parallelly scanned through the object
- that the cylinder, with the exception of arrangements for guidance and suspension, consists of a a collimator part with the diametre larger than the width of the radiation emitter, and with an open slit along this part of the cylinder
- that the open slit passes through or near the centre of the cylinder
- that the open slit is symmetrically (uniformly) and helically encircling the cylinder

2. Movable, scanning radiation emitter for the emission of a ionized, electromagnetic bundle of beams for the steplessly adjustable collimation together with rotating, cylinder-shaped arrangements of lead or other radiation absorbing material (collimators) c h a r a c t e r i z e d b y t h e f a c t

- that the target of the electronic beam is movable, and is moved according to a predetermined, regular moving pattern along the lengthened anode
- that the radiation emitter is placed near, and in front of the rotating, cylinder-shaped arrangements (collimators)
- that the x-ray beam is parallelly scanned through the object
- that each cylinder, with the exception of arrangements for guidance and suspension, consists of a collimator part with the diametre larger than the width of the radiation emitter, and with an open slit along this part of the cylinder
- that the open slit of each cylinder passes through or near the centre of the cylinder
- that the open slit of each cylinder is symmetrically (uniformly) and helically encircling the cylinder

- that two or more cylinders are either mounted within each other or parallelly to each other, and that the cylinders are moved or turned in relation to each other or that a combination of these movements takes place

3. Arrangements according to claim 1 or 2 characterized by the fact

- that the cylinder or cylinders are mounted parallelly to the moving direction of the movable radiation emitter, with the "collimator hole" of the cylinder or cylinders, and a straight line between the end positions of the movable radiation emitter in one and the same plane, the scanning plane
- that the direction and velocity of the rotating cylinder or cylinders are adapted to the moving direction and moving velocity of the movable radiation emitter, so that a scanning x-ray beam is produced

4. Movable, scanning radiation emitter for the emission of a ionized, electromagnetic bundle of beams to be used with or without collimator characterized by the fact

- that the target of the electronic beam is movable, and is moved according to a predetermined, regular moving pattern along the lengthened anode
- that, if collimation takes place, other types of collimators are used than those mentioned according to claims above

FIG 1

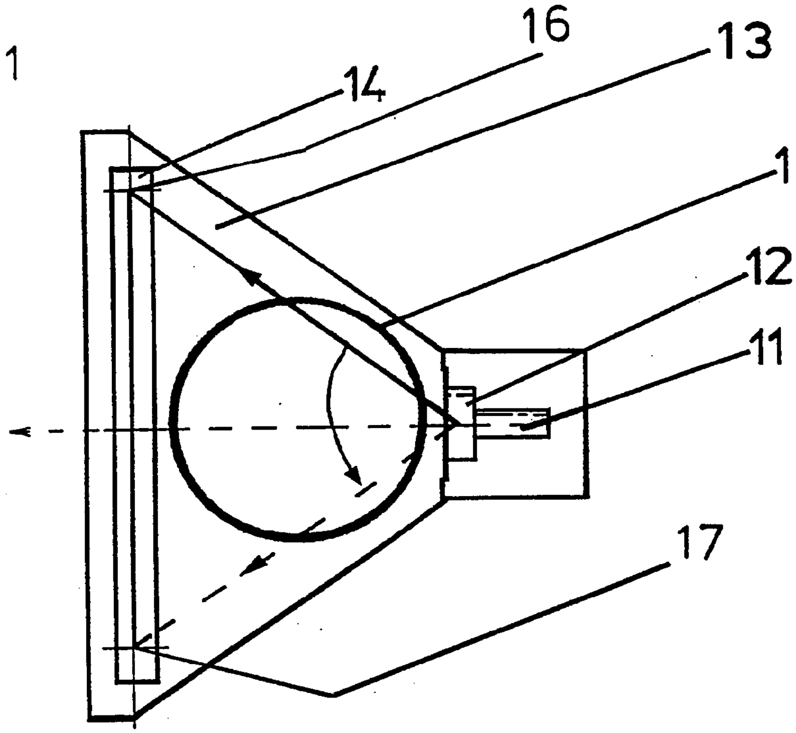

FIG 2

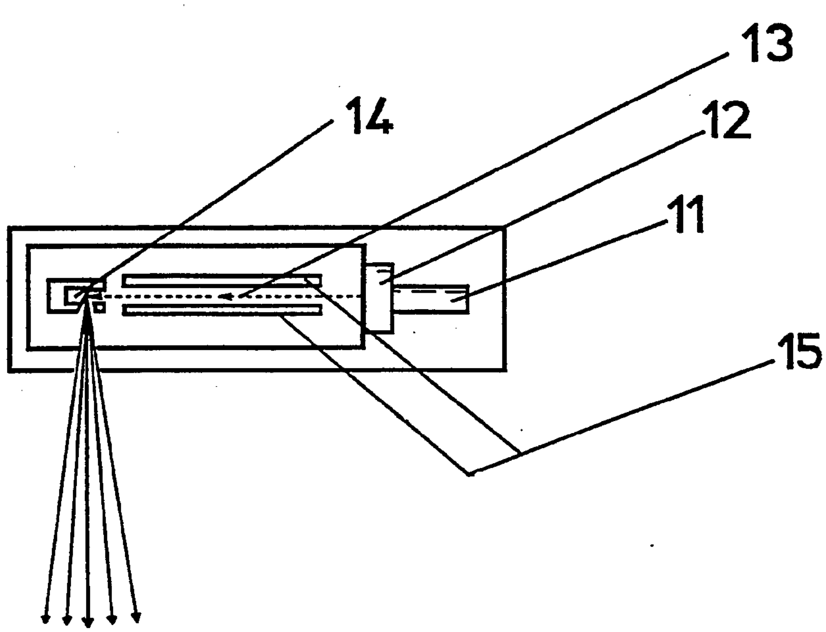

FIG 3

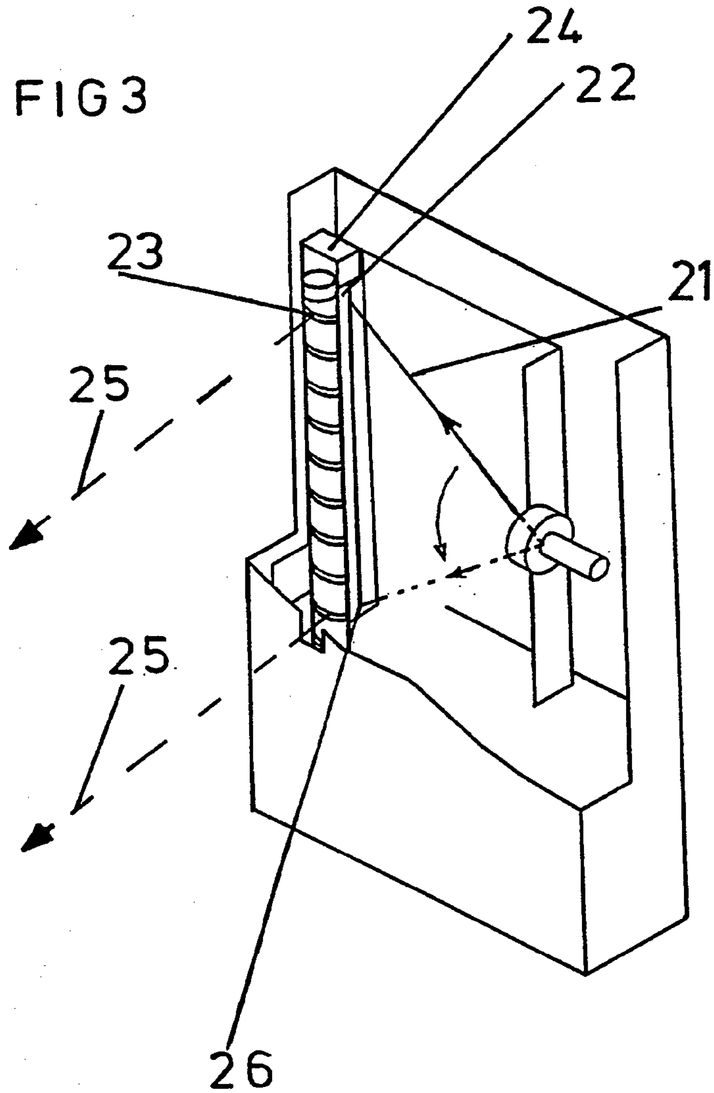

FIG 4

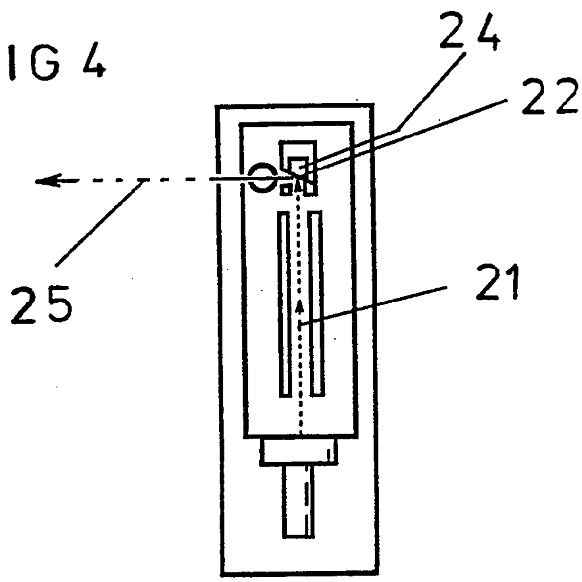

FIG 5

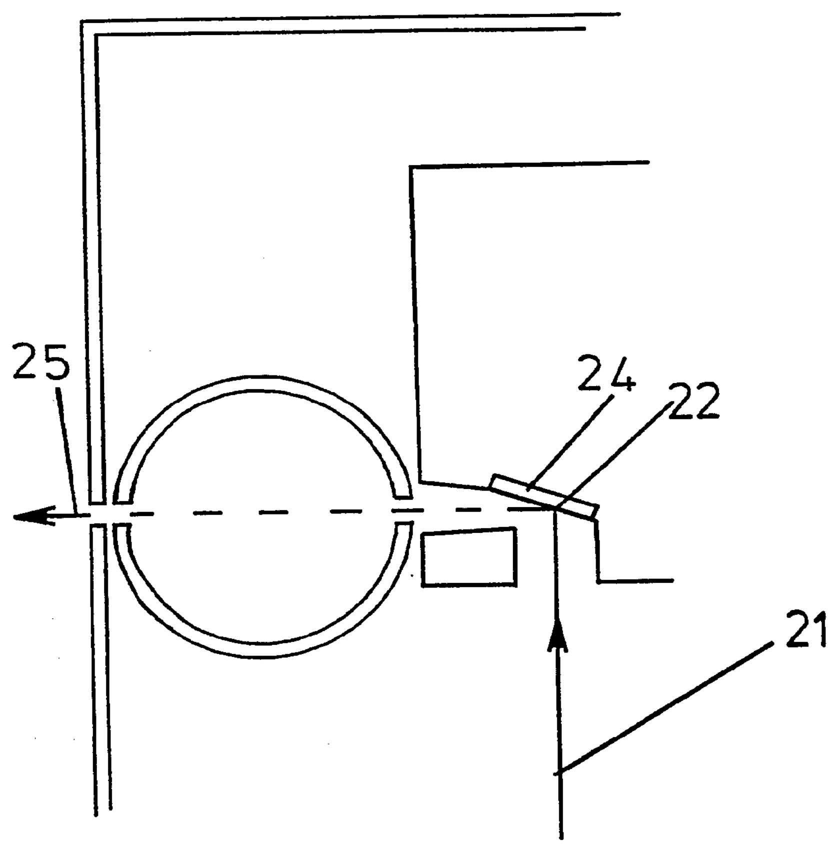

FIG 6

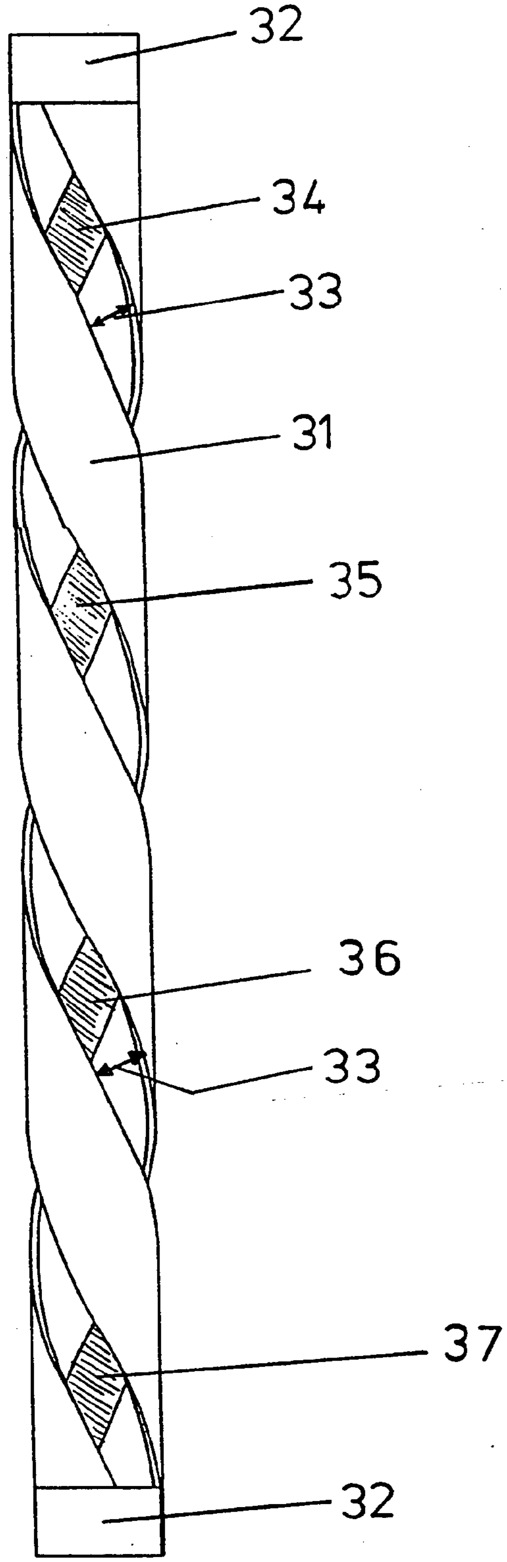

FIG7

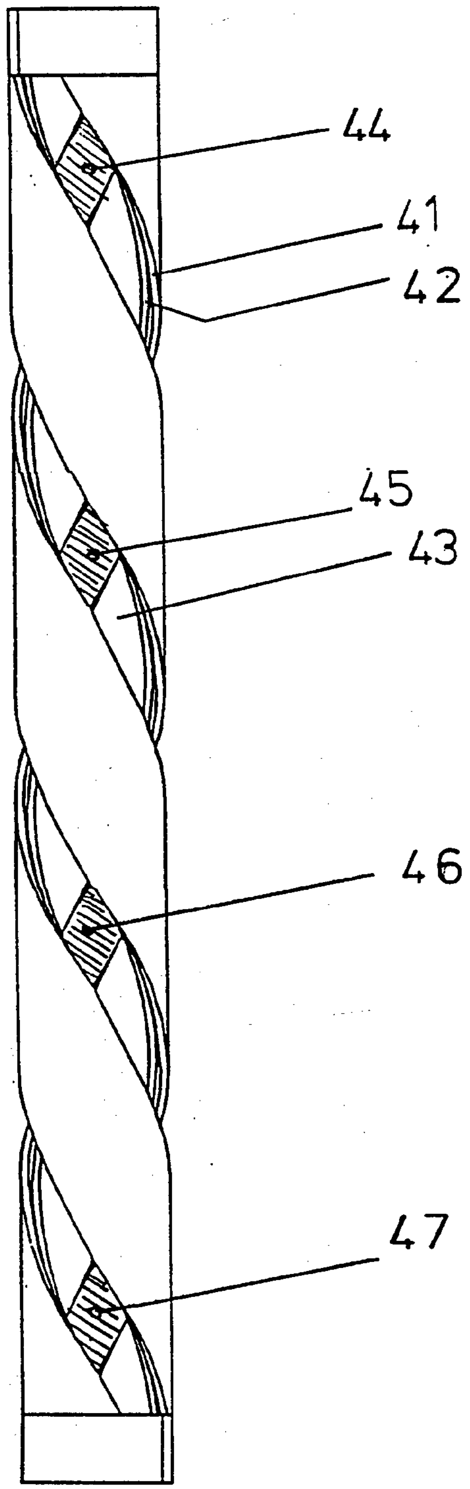

FIG8